CERTAIN VALLEY CONFIGURATIONS IN LOW LATITUDES

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To those who have studied the physiographic features of the tropics, the phenomena described in this paper may be quite familiar, but they do not appear to be well known to the average worker in the higher latitudes, and this is our warrant for publishing what at best are but passing notes. If the phenomena have been critically examined by students of tropical physiography it is to be hoped that they may be stimulated by the imperfections of these notes to publish the fuller truth for the benefit of geologists of the mid-latitudes.

In September, 1906, while riding on the Ferrocarril Mexicano from Esperanza on the high plateau down to Vera Cruz on the Gulf, the attention of the writers was caught by the fact that there was practically no talus at the base of the slopes, even when these slopes were steep and rocky. The peculiar configuration of the valley profiles also arrested attention. Further observations made it clear that these features were prevalent. Preliminary to their discussion, it may be remarked that the Mexican plateau has an elevation of some 7,000 feet above the sea. At its eastern border the tableland ends rather abruptly so that the railroad takes advantage of several deep valleys heading back into the plateau and makes frequent windings on their steep slopes to accomplish its descent to the coastal plain. At first tributaries and then the main stream of the Rio Blanco are followed to the city of Orizaba amid impressive scenery. Between Orizaba and Cordoba the railway passes from the valley of the Rio Blanca to the basin of the Rio Atoyac. Beyond Cordoba, the railway line crosses a series of tributaries of the Rio Atoyac through a region of steadily declining relief. The best expressions of the distinctive configuration of the valleys lie in the upper and steeper portions but in some degree they persist throughout.

Above Orizaba the valley slopes are distinctly steep though not strictly precipitous; and yet in favorable localities the stream possesses

a moderate flood plain, giving the valley a measurably flat bottom. It was observed that wherever the valley floor joins the steep valley sides and might be expected to rise into them with a broad free curve, there is instead almost universally a short sharp curve, almost an angle. There is almost no wide open sweep of the surface from the low slope of the bottoms to the steep slope of the valley sides, such as is so common in the mountainous parts of the United States and in higher latitudes generally, so far as we have seen them. In the higher latitudes the foot of a steep slope of indurated rock of this sort is usually buried beneath a belt of talus and mantle rock which serves to merge the high declivity of the valley side by an open concave swing into the low declivity of the valley bottom. In this tropical Mexican valley the slopes are clean and steep all the way down to the immediate vicinity of the flat bottom into which they turn almost at an angle. On the slopes there is only a very scant sheet of mantle stuff adhering to the rock in place, but yet this mantle supports a luxuriant vegetation. The scree slopes, so familiar in like situations in higher latitudes, are almost entirely absent.

In January, 1909, during a brief visit at Honolulu, we were able to make a hasty study of the Nuuanu Valley which leads up the southern slope of the island of Oahu to the Pali, a striking viewpoint on the backbone of the island. Compared with northern configurations, this valley impressed us as unique in its profiles and, while recalling the Mexican phenomena, was not altogether identical with them. The mountain slopes on either side are exceptionally steep, rising when at their maximum with angles of scarcely less than 60°, as near as the eye could measure; and yet they are generally clothed with vegetation, though the bare rock comes to the surface at many points in the midst of the luxuriant vegetal growth. These slopes are well creased by erosion trenches, giving the valley side a corrugated aspect. Except locally, soil is not abundant in the upper part of the valley, even on the bottoms. There appears to be little or no talus at the base of the slopes, which curve sharply into the valley bottom, much as in the Mexican case. The valley bottom presents a general aspect of planeness, but is rough in detail and usually quite rocky.

One of the noteworthy features of the valley is its peculiar cross-

section. It partakes more nearly of the features of a U-shaped glacial valley than of the typical V-shaped valley familiar to geologists as the product of running water at high gradients; but obviously glacial action has had nothing to do with the sculpturing of this valley. It may be exceptional in this feature, which is possibly dependent on differences in the character of the lava that makes up this part of the island. Unfortunately we were unable to visit any of the other valleys of the island. The lack of talus at the foot of the usually steep slopes was notable and in full consonance with the similar absence in the valleys on the eastern border of the Mexican plateau.

On a railway journey from Yokohama to Kyoto, Japan, in latitude about 35° N., the relation of the broad flats of the lowlands to the higher slopes of the uplands attracted especial attention. As in the preceding cases, their junctions were decidedly more abrupt than is usual in like cases in our northern latitudes in America. The first impression received, due no doubt to inherited geologic habit, favored the assignment of the flats to sea work and the abrupt angle they made with the uplands to the girdling of the sea margin. This view, on closer study, seemed probably erroneous. The plains appeared to be aggradation bottoms, in the main, built up or at least sheeted over by the numerous rivers that emerge from the mountains. The streams across them have notable gradients. The abruptness is thus probably in part constructive, rather than erosional, but is probably also in part erosive and perhaps of the Mexican type.

In South China features of an analogous order were noted. The Si Kiang, or West River, has a long course through the moderately mountainous country which is characteristic of Southern China. From the bottoms that adjoin the river, the hill slopes usually rise promptly and steeply. The mountain range west of Sam Shui in the province of Kwang Tung was estimated to reach 1,000–1,200 feet and perhaps at points 1,500 feet in elevation. Very little talus was seen on its slopes or on any of the mountain slopes. The soil is thin, and under the climatic conditions prevailing here the hills have a limited vegetal covering and are very scantily cultivated. There are, however, lower hills that are often well rounded, with clean, smooth slopes.

From the town of Wuchow in the province of Kwang Si an ascent of a prominent peak, 1,200 feet above the town, gave a commanding view of the general topography of the country about the junction of the Si Kiang and Kwei Kiang. The erosion of this region, working upon an older elevated peneplain of undetermined geologic date, has been very pronounced. Almost everywhere sharp V-shaped valleys with very straight, even-sided slopes prevail. There is prac-

FIG. 1—Bowlders of exfoliation near Kowloon on the Asiatic mainland opposite Hong Kong.

tically no talus or aggradation accumulations until the river level is approached.

In contrast to the above, among the White Cloud hills near Canton, in Kwang Tung, there are extensive accumulations of arkose material. In fact, the solid rock, which is of the granitic type, is almost everywhere buried beneath its own disintegrated products. A similar condition in even more pronounced form was observed at Kowloon on the Asiatic mainland, opposite Hong Kong. In many of the cuts for the new railroad now being constructed from Kowloon to Canton

many feet of disintegrated material were found above the more indurated granite into which the arkose graded slowly. This granite in its upper portion is soft and partially disintegrated. In its lower portion certain "bowlders" or less disintegrated portions in it were being quarried for building purposes. It was not altogether clear whether the "bowlders" are to be regarded merely as residual remnants of a once homogeneous mass left by the unequal progress of disintegration, or whether the whole was a secondary deposit of mixed arkose and bowlders derived from the adjacent hills and once partially cemented together, but which has more recently again resumed its disintegration. There are some reasons for believing that both alternatives are true in different portions of the district. In those localities where deep disintegration prevails, the upper slopes merge into the lower slopes in the gradual, curving way common in higher latitudes.

The main purpose of these notes is to lay emphasis on the relatively sharp angle between the valley sides and the valley bottoms observed in several of these regions of low latitude. In part this feature may, no doubt, be said to be due to the comparative absence of talus at the foot-slope of the valley sides, but this is probably not the whole truth of the matter. The relative absence of coarse talus of a certain kind in low latitudes is recognized as assignable to the absence of freezing temperatures by virtue of which the repeated expansion of water in joint planes, cracks, and pores disrupts the surface rocks and loosens masses which roll to the foot of the slope.[1] The localities named in this paper, except that in Japan, are all within the border of the tropics and this explanation is applicable so far as it goes. Talus piles and scree slopes of the frost type are obviously excluded by the climatic conditions. Bowlders due to exfoliation, which we found so abundant at Kowloon, are probably absent in the localities characterized by thin soils because in these cases the decay proceeded more uniformly and slowly from the surface and was more largely confined to the surface instead of penetrating deeply along the joints and working from them toward the centers of the blocks between the joints. This limitation of action was probably due in turn to the close texture of the rock in the Mexican, Oahu,

[1] J. C. Branner, "Decomposition of Rocks in Brazil," *Bull. G. S. A.*, Vol. VII, 1896, p. 268.

and Kwang Si cases. In the Canton and Kowloon cases granular disintegration prevailed in a marked degree, as is well known to be common in low latitudes, but in these cases the rock was granitic and peculiarly susceptible to this mode of disaggregation. In the Mexican and Oahu localities the rocks were mainly close-textured lavas; in Kwang Si fine-grained sediments, in the main. Under the influence of a warm climate, aided by the tropical vegetation, the rocks of these localities seem to pass into soil on the surface with little detachment of blocks, bowlders, or other coarse material. The rains of these regions are sufficient to keep the soil thin in spite of the vegetal protection and thus to keep the decay working actively on the whole outer surface.

While this seems to explain the nature of the surface and the thin surface mantle, we are not fully persuaded that it altogether explains the abruptness of the change from the side slopes to the valley bottoms. Without attempting to give very cogent reasons for the interpretation, we are disposed to refer this to a mode of hydraulic action which is really normal but which seems abnormal to us because in mid-latitudes it is commonly thwarted by an overburden of detritus. During a rain the water on the slopes grows in amount as the slope is descended and the wash-action is normally greatest at the foot of the slope if the water has not become overloaded with detritus in its descent. The velocity of flow also increases as the slope is descended and this further adds to the erosive power toward the base of the slope. A normal slope should therefore approach more and more to the vertical as it gains in descent. This is almost universally true of the brow and upper part of the slope in all latitudes. Why does it not persist to the bottom? In certain cases it does. Certain mesas, buttes, and outliers, particularly in arid lands, possess essentially vertical sides which reach down either to coarse talus piles or to the horizontal beds of the surrounding region. In some instances there is sapping at the base due to more perishable layers but in other cases there is no sign of this and the cutting at the base appears to be due to the superior volume and velocity of the water rushing down the sides. In these cases the effect is probably correlated with the absence or scantiness of vegetation which when present restrains the rush of the waters. A similar effect is shown in waterfalls, though here differ-

ences of rock resistance usually overshadow it and the joint result has an abnormal expression. Erosion is markedly greatest at the foot of the falls where deep excavation and undercutting are pronounced. A better case for the present comparison is the development of rapids and cascades into vertical falls by the greater erosion at the base of the plunge, even in cases where the rock is essentially homogeneous.

In all these cases the superior erosion due to superior velocity or volume or both is carried only to a certain extent because it meets restraint in the supporting effects of the neighboring rock, and this is probably the key to the solution of that balance of effects seen at the foot-slopes of valleys. While the floods from the slope increase in volume and velocity all the way down the steeper part of the slope, and considered by themselves alone should increase the slope even to verticality, the flat-lying rocks of the valley bottom lend support to the foot of the slope by giving a less proportion of exposure and a higher ratio of adhesion to its surface parts and thus render their removal less easy than they would be in the absence of such support. If this is not quite obvious it may perhaps become clear on picturing a vertical wall formed of spherical granules meeting a horizontal surface of like kind at right angles and noting the individual conditions of the granules. If A represents a granule at the angle, BB′B″, etc., the successive granules above it in the face of the vertical wall and CC′C″, etc., the successive granules in the horizontal face, it is clear that A will be least easily removed because only 90° of its circumference is exposed while 270° is both protected and attached, whereas 180° of the circumference of the B and C granules is exposed and only 180° protected. With equal wear the B and C granules must suffer most and the angle gradually pass into a curve. In a similar way it may be seen that the granules that form a short concave curve are less exposed and have more attachment than the granules of a more open concave curve, or of a plane or convex curve. Each portion of the slope is thus dependent, in a measure, on the support of the other portions and the flat portion of the valley bottom may be said to support the rock at, and near, the angle and cause the development of a curve which represents the working balance between the agencies of erosion and of resistance. By this curve the increasing flood from the slope is

gradually turned from its nearly vertical descent into a more nearly horizontal course.

The meaning of the short curve as distinguished from a longer curve lies in the balance of the co-operating agencies. A good mantle of vegetation when present measurably restrains the plunging waters and somewhat softens the curve of transition. In the absence of vegetation, the abrupt mesa-cliff on the one hand and the vertical or even overhanging falls on the other are liable to develop. The abrupt curve at the foot-slope in the tropical cases described is thus referred to a co-operation of agencies in which (1) the absence of talus-making causes, (2) the prevalence of minute surface decay, (3) the restraint of vegetation, and (4) the concentration of the wash toward the foot-slope are conjoined. This phase of action seems to be prevalent in low latitudes, but not equally so in high latitudes.